



# Critical care echocardiography in prone position patients during COVID-19 pandemic: a feasibility study

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## Abstract

**Purpose** Critical care echocardiography is a fundamental tool in the hemodynamic evaluation of critically ill patients and prone position ventilation might limit its application. We aim to evaluate the feasibility of transthoracic echocardiography to assess different measurements performed in prone vs supine position in patients during COVID-19 pandemic to answer our research question: What is the feasibility of classic echocardiographic measurements in COVID-19 patients in prone position ventilation?

**Methods** Patients with covid-19 admitted to ICUs in four academic hospitals with respiratory failure and on mechanical ventilation were evaluated with critical care echocardiography. The first ultrasound assessment was compared between prone and supine patients recording feasibility of several echocardiographic measurements, using Fisher's exact test complementing with Crombach's Alpha.

**Results** 139 patients were included. Sixty-eight (49%) were evaluated in prone position and seventy one (51%) in supine position. Most variables were highly feasible, left ventricular volumes and ejection fraction were more possible to obtain in prone position, while cardiac output was in supine position. Tricuspid regurgitation was the least feasible overall measurement.

**Conclusion** Prone position ultrasound achieved a high feasibility of measurements compared with supine ultrasound in critically ill patients with COVID-19 respiratory failure and on mechanical ventilation.

**Registration** Post hoc analysis of Echo-COVID study (NTC04628195, registered November 13, 2020, retrospectively registered).

**Keywords** COVID-19 · Respiratory insufficiency · Echocardiography · Prone position · Mechanical ventilation · Critically ill

## Background

Critical care echocardiography (CCE) is nowadays recommended as the first line evaluation technique in hemodynamically unstable patients, particularly to diagnose type of shock and guide the hemodynamic resuscitation; CCE allows the operator to perform qualitative assessments, quantitative measurements and real time follow-up [1, 2].

Covid-19 pandemic has imposed a work overload on healthcare staff in intensive care units (ICUs) with patients with severe respiratory failure and high mortality rates [3–6] many of them requiring prone position as recommended in acute respiratory distress syndrome (ARDS) guidelines [7]. It is known that during ARDS the right ventricle (RV) can be compromised and its evaluation becomes important to adjust ventilation parameters, in particular for detection of

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acute cor pulmonale pattern (ACP), considering its association with poor outcomes and its more frequent presentation in the most severe ARDS patients [8–11].

In this context, with higher workload and increased number of patients, transthoracic CCE in prone position might be a valuable tool for quicker and simpler evaluation in comparison to the transesophageal approach, and since the technique was reported [12] it has been increasingly described in recent series with new updates and variations, particularly during the current pandemic [13–15]. Thus, our research question: What is the feasibility of classic echocardiographic measurements in COVID-19 patients in prone position ventilation?

Our objective was to describe the feasibility of different echocardiographic measurements performed in prone vs supine position in COVID-19 patients during the current pandemic season in four academic centers in Chile.

## Material and methods

This study is a post hoc analysis of Echo-COVID study (NTC04628195). From March to June 2020, COVID-19 patients admitted to ICUs in four academic hospitals in Chile were evaluated with repeated cardiac ultrasound. Patients were included if they were admitted to ICU and were on mechanical ventilation with confirmed positive COVID-19, either by polymerase chain reaction test or a positive Computer Tomography with serology; and respiratory failure was attributed to covid-19. We excluded patients with no ultrasound window.

From this cohort we evaluated the first cardiac ultrasound performed identifying those done in prone or supine position and evaluating the feasibility of measurements.

The prone position echocardiography was performed in the left swimmer position as previously described [12], aiming to obtain apical view and related measurements. Supine views were performed without modifications to patient position. All ultrasounds were performed by operators with at least two years of critical care ultrasound experience. Only one operator evaluated each patient.

We included primary measurements, usually used alone or in calculations that allow characterization of left and right ventricular systolic and diastolic function and orientation about fluid status. We included the feasibility of qualitative assessment of septal movement considering the relevance of right heart function in COVID-19 and cor pulmonale. In addition, the feasibility of calculated relevant variables was included. The list of variables evaluated were: Left ventricle (LV) end diastolic and end systolic volume in four chambers view, MAPSE, TAPSE, right ventricle (RV) end diastolic area in four chambers view, LV end diastolic area in four chambers view, trans-tricuspidal gradient, septal

morphology, mitral A wave, Mitral E wave, tissue doppler (TD) s' and e' mitral waves, TD s' tricuspid wave, LVOT (left ventricle outflow tract) velocity time integral (VTI) and inferior vena cava (IVC) maximum and minimum diameter. LVOT diameter is obtained in the parasternal window and feasibility was not recorded given its intrinsic impossibility in prone position. The following “integrated” variables feasibilities were recorded and compared: Cardiac output, LV ejection fraction, acute cor pulmonale (ACP) detection, diastolic function and fluid responsiveness using IVC despite known limitations. Feasibility was dichotomic, either feasible or not feasible. Any measurement that was not recorded by the operator was defined as not feasible.

Echocardiographic measurements were obtained with a Vivid i echocardiography system (GE Medical Systems, Milwaukee, WI, USA), Philips CX 50 (Philips Healthcare, DA Best, The Netherlands), Mindray M9 (Bio-Medical Electronics Co., Shenzhen, China), and Sonosite M-Turbo (FUJIFILM Sonosite, Inc. Bothell, WA, USA), as used in each center. Invasive measurements were not available since pulmonary artery catheter use is uncommon in our centers.

Ethical approval was granted from local ethics boards of each center (ID: 20042,002).

The proportion of feasible measurements was obtained, described and then the proportion of each one was compared using Fisher's exact test in SPSS 20 between supine and prone group, *p* value under 0.05 was considered statistically significant. We evaluated Cronbach's  $\alpha$  for 2D (LVOT diameter, LV end diastolic and systolic volumes, LV ejection fraction, MAPSE, TAPSE, RV and LV end diastolic areas, IVC minimum and maximum diameters) and doppler (trans-tricuspidal gradient, mitral A and E waves, s' and e' mitral waves, s' tricuspid wave, LVOT VTI) measurements in supine and prone position groups.

## Results

One hundred sixty patients were evaluated for 4 months. 21 patients were excluded because no ultrasound window could be obtained, twelve (14.46%) in supine position and nine (11.69%) in prone position with no significant difference. Finally, 139 patients were included for analysis. Sixty-eight patients (49%) were evaluated in prone position and seventy-one (51%) in supine position. Clinical and demographic characteristics are summarized in Table 1, no difference between groups was observed, the group overall included mostly males around 55 years old with a week of COVID-19 symptoms before admission and 9–10 before ventilation.

The feasibility of different echocardiographic measurements, calculation and integrated variables are shown in Table 2, for all patients in both groups with the appropriate statistical comparisons. Most variables showed high

**Table 1** Demography and clinical characteristics

Variable	All patients	Prone	Supine	<i>p</i> value*
Sex, male (%)	99 (71.22%)	48 (70.59%)	51 (71.83)	0.51
Age, years +	57.21 + 11.61	55.76 + 11.41	58.58 + 11.70	0.15
Height, m +	1.67 + 0.09	1.67 + 0.09	1.68 + 0.10	0.699
Weight, Kg +	86.53 + 17.99	87.69 + 18.36	85.46 + 17.70	0.479
SOFA score at ICU Admission +	6.29 + 2.63	6.55 + 2.91	6.00 + 2.27	0.261
APACHE II +	14.47 + 6.29	15.57 + 6.63	13.29 + 5.74	0.50
Day of symptoms before Hospital admission*	7 [5–9.25]	7 [4–8]	7 [5–10]	0.363
Hospital length of stay before ICU admission*	1 [0–3]	1 [0–5]	1 [0–3]	0.151
Days of symptoms before MV*	9 [7–13]	9 [6.75–13]	10 [7–13]	0.659

ICU intensive care unit, MV mechanical ventilation

\*Median and IQR, Mann Whitney test

+ Mean and standard deviation, *T*-test

**Table 2** Absolute frequency and proportion of feasibility of echocardiographic variables

Evaluated variable	All patients ( <i>n</i> = 139)	Prone ( <i>n</i> = 68)	Supine ( <i>n</i> = 71)	<i>p</i> value*
Direct measurements				
Absolut frequency (proportion %)				
LV end diastolic volume	124 (89.21%)	65 (95.59%)	59 (83.10%)	<b>0.016</b>
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MAPSE	130 (93.53%)	64 (94.12%)	66 (92.96%)	0.527
TAPSE	137 (98.56%)	67 (98.53%)	70 (98.59%)	0.741
RV end diastolic area	135 (97.12%)	67 (98.53%)	68 (95.77%)	0.326
LV end diastolic area	134 (96.40%)	67 (98.53%)	67 (94.34%)	0.197
TR gradient	59 (42.45%)	32 (47.06%)	27 (38.03%)	0.183
Septum morphology	120 (86.33%)	56 (82.35%)	64 (90.14%)	0.138
Mitral E wave	137 (98.56%)	67 (98.53%)	70 (98.59%)	0.741
Mitral A wave	132 (94.96%)	67 (98.53%)	68 (95.77%)	0.476
Mitral S' wave	132 (94.96%)	65 (95.59%)	67 (94.34%)	0.524
Mitral e' wave	133 (95.68%)	65 (95.59%)	68 (95.77%)	0.639
Tricuspid S' wave	131 (94.24%)	64 (94.12%)	67 (94.34%)	0.616
LVOT VTI	134 (96.40%)	65 (95.59%)	69 (97.18%)	0.479
Maximum IVC diameter	112 (80.58%)	52 (76.47%)	60 (84.51%)	0.163
Minimum IVC diameter	112 (80.58%)	52 (76.47%)	60 (84.51%)	0.163
Integrated and calculated variables				
Cardiac Output	110 (79.14%)	45 (66.18%)	65 (91.55%)	< <b>0.001</b>
Ejection fraction	124 (89.21%)	65 (95.59%)	59 (83.10%)	<b>0.016</b>
ACP pattern evaluation	134 (96.40%)	67 (98.53%)	67 (94.34%)	0.197
Diastolic function evaluation	127 (91.37%)	62 (91.18%)	65 (91.55%)	0.587
Fluid responsiveness	112 (80.58%)	52 (76.47%)	60 (84.51%)	0.163

LV left ventricle, MAPSE Mitral annular plane systolic excursion, TAPSE tricuspid annular plane systolic excursion, RV right ventricle, TR tricuspid regurgitation, LVOT left ventricle outflow tract, VTI velocity time integral, IVC inferior vena cava, ACP acute cor pulmonale

\*One sided Fisher's exact test

In bold letters those < 0.05

feasibility with no differences between prone and supine patients with a feasibility over 80% in most of them. However, there were statistically significant differences in left ventricular volumes and ejection fraction evaluation in four chambers, favoring prone position (96% vs 83%,

respectively), and in cardiac output calculation favoring supine position (92% vs 66%). The measurement with the lowest feasibility was tricuspid regurgitation with no differences between the two groups (42% overall).

Cronbach's  $\alpha$  for 2D measurements was 0.68 in supine and 0.64 in prone position,  $\alpha$  for doppler measurements was 0.47 in supine and 0.41 in prone position.

## Discussion

Our results show that CCE in prone ventilation has a high feasibility for many of the fundamental measurements and observations in "real-life" complex patients, particularly in the acute and most critical stage of COVID-19 respiratory failure when compared to similar patients in supine position; but some variables showed significant differences. We observed that cardiac output calculation was less feasible for prone position patients, considering that left ventricle outflow tract was equally obtained, the limitation in prone position was measuring the outflow tract diameter, which requires a long parasternal axis that is not possible in prone position ventilation. However, obtaining the outflow diameter in the patient just before being turned prone would allow the calculation of the cardiac output, as some of our team members did.

In contrast, left ventricle volumes and ejection fraction were more feasible in prone position, this is possible because of the improved apical view considering the favourable position of the heart against the chest wall in swimmer's prone position.

As for the other variables no difference was shown. We obtained a high overall feasibility considering that critical care patients might not present adequate windows in up to 40% in expert operator hands [16, 17]. Since prone position ultrasound is focused on the apical view, a good result was to be expected in aortic and mitral flow evaluations, chamber and ejection estimation and tissue Doppler measurements. It is noteworthy that the most critical measurements such as LVOT VTI were obtained in more than 90% of cases, which is relevant to perform dynamic manoeuvres for better characterization of the hemodynamic condition of each patient and fluid or inotrope tailoring if required [16–19]. Variables that were harder to obtain in both groups include IVC diameters (around 80%) and particularly tricuspid gradient, possibly because of window limitations or small gradient regurgitations that did not allowed appropriate tracing.

Another relevant aspect is the high proportion of RV evaluation to discern whether ACP was present, this requires appropriate septal evaluation and RV/LV area measurements, and a high proportion of achievement is paramount in ARDS particularly in severe cases requiring prone position [8–11]. Considering the good feasibilities, the requirement of a transoesophageal examination [20] for undetermined cases should be reduced, diminishing resource utilization, particularly in the present pandemic setting.

The obtained Cronbach's  $\alpha$  suggest a better consistency for 2D measurements than doppler derived variables.

This study has several limitations, it was performed only in academic centers having operators with prone CCE experience, thus, feasibility could be worse in unexperienced hands and these results might not represent results in non-academic hospitals. However, in our opinion, prone position ultrasound is very similar to supine position and considering that the heart becomes in close contact with the chest wall [21] the views might be even easier to obtain even for a basically trained operator; in addition, we think that prone position ultrasound should be considered as part of conventional training and practiced whenever it is possible for the trainee considering the valuable information in can provide.

## Conclusion

Cardiac ultrasound in prone position allows hemodynamic evaluation in COVID-19 patients comparable to traditional supine position ultrasound with better feasibility for LV volumes and ejection fraction and worse for cardiac output.

**Author contributions** EDV and JNM planned this analysis, all authors performed ultrasound on patients and obtained primary data, DU and EDV performed statistical analysis, DU wrote the first draft, DU, PM, JNM and EDV refined the final manuscript. All authors approved the final document.

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**Availability of data and material** The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

**Code availability** Not applicable.

## Declarations

**Conflicts of interest/Competing interests** The authors declare that they have no competing interests.

**Ethics approval** Ethical approval was granted from local ethics boards of each center (ID: 200422002).

**Consent to participate** Consent was waived given the observational nature of the study.

**Consent for publication** Not applicable. The manuscript does not contain personal data.

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